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Synthetic Vision Systems (SVS)
Description of Candidate Concepts Document, FY 00

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1.0 INTRODUCTION

This document supports work done under NASA Contract NAS1-20342 Task 35, titled "Synthetic Vision Systems Concept Assessment, And Flight Integration Operational Inputs". Specifically, efforts herein are intended to satisfy Deliverable Number 3 in the Statement of Work, titled "Description of Candidate Concepts Document". This document describes the current baseline Synthetic Vision Systems (SVS) Concept. This document summarizes the efforts and inputs of a number of individuals on the Synthetic Vision Systems (SVS) Team from a number of industry and government organizations. It is a snapshot of the current concept, with some team member variations, as it exists at the end of Calendar Year 2000. As the Concept is in early stages of development, much of the defining activities and studies are in progress as of the date of this document, or have final reports or analysis pending. As the Concept matures, updated descriptions will be published, with the next update scheduled at the end of Fiscal Year 2001.

1.1 PURPOSE

The purpose of this document is to characterize the current SVS Candidate Concept, including key components of the Concept, and issues associated with selection of technologies and components. The demonstrated or analyzed capability and potential of existing candidate SVS concept components in satisfying Commercial and Business (CAB) Transport Aircraft mission requirements is included.

1.2 BACKGROUND

1.2.1 Aviation Safety Program

In August 1996, following the wake of several high-visibility commercial transport accidents, a White House Commission on Aviation Safety and Security was established to study matters involving aviation safety and security. The Commission findings concluded that although the worldwide commercial aviation major accident rate is low and has been nearly constant over the past two decades, increasing traffic over the years has resulted in the absolute number of accidents increasing. Given the very visible, damaging, and tragic effects of a single major accident, this situation could become an unacceptable blow to the public's confidence in the aviation system. As a result, the anticipated growth of the commercial air-travel market would not reach its full potential. In February 1997, in response to the Commission's recommendations, President Clinton set a national goal to reduce the aviation fatal accident rate by 80% within ten years. NASA's role in civil aeronautics is to develop high risk, high payoff technologies to meet critical national aviation challenges. Currently, a high priority national challenge is to ensure U.S. leadership in aviation in the face of growing air traffic volume, new safety requirements, and increasingly stringent noise and emissions standards. NASA has a successful history of leading the development of aggressive high payoff technology in high-risk areas, ensuring a proactive approach is taken to developing technology that will both be required for meeting anticipated future requirements, and for providing the technical basis to guide policy by determining feasible technical limits. Therefore, NASA has stepped up to the challenge of addressing the President's national aviation safety goal by forming the new, focused Aviation Safety Program. As a first step to establish a focused safety program, NASA sponsored a major program planning effort to gather input from the aviation community regarding the appropriate research to be conducted by the Agency. This activity called the NASA Aviation Safety Investment Strategy Team (ASIST), held four industry- and government-wide workshops to define and recommend research areas, which would have the greatest potential impact for reducing the fatal accident rate. NASA then redirected existing research and technology efforts and formulated new ones to address the safety needs defined by ASIST.

1.2.2 Synthetic Vision Systems Project

One of the significant recommendations from ASIST was to establish a project to eliminate visibility-induced errors for all aircraft through the cost-effective use of synthetic/enhanced vision displays, worldwide terrain databases, and Global Positioning System (GPS) navigation. Therefore, on March 25, 1999 the Associate Administrator for Aerospace Technology, Spence Armstrong, signed the Project Formulation Authorization for the Synthetic Vision Systems Project. The Synthetic Vision Systems Project emphasizes the cost-effective use of synthetic vision displays (both tactical and strategic), worldwide navigation, terrain, obstruction and airport databases, integrity monitoring and forward looking sensors as required, and Global Positioning System-derived navigation to eliminate "visibility-induced" (lack of visibility) accident precursors for all aircraft and rotorcraft.

Studies concerning the SVS Project mission have been framed around, and developed, several candidate concepts (aggregate system and component characterizations) for satisfaction of mission requirements and reduction of technical and certification risk. Studies, simulation experiments, and flight test experiments have been devoted to exploring research issues associated with, and assessment of elements contained within, these concepts. As the SVS Team is composed of representatives from several organizations, some of which are planning on marketing their own SVS concepts eventually, there are variations in concept definition specifics, particularly with respect to display formats and operational philosophy. The current document will summarize the present definition of those concepts and variations, at an upper level. Concept definitions will necessarily change as the Program matures, lessons are learned, and down selects occur. This Concept Definition Document will be updated yearly to document those changes.

1.3 SCOPE

This document is intended to be an upper level summary of concept definition. Detailed descriptions of research hardware, software, and system architecture may be found in the requirements documents for each of the experiments, rather than contained herein.

Component descriptions and characterization are documented as they are known as of the date of this report. Changes resulting from meetings or reports released subsequent to this report date will be incorporated in the next update of this document, planned annually.

1.3.1 Components

For purposes of this task, the SVS Concept is assumed to consist of the following elements (elements will be discussed individually in a later section):

1.3.1.1 SVS Sensors (or sensor equivalents)

- Forward Looking Infrared (FLIR) (potential)
- Weather Radar (Potential SVS Modes)
- Millimeter Wave Radar (potential)
- Onboard SVS Data Base

1.3.1.2 Displays

- Primary Flight Display, or imbedded display features
- Navigation Display, or display features/pages
- Head Up Display (option) with dedicated display features
- Interface with Other Cockpit Displays, i.e., TAWS

1.3.1.3 Computers/Imbedded Computational Functions

- Image Object Detection and Fusion
- System Integrity, Verification and Validation
- SVS Computations and Symbol Generation

1.3.1.4 Equipment

- Dedicated SVS Support Equipment and Crew Interface
- Interface with Other Aircraft Systems

1.3.1.5 Associated Aircraft Systems

- Differential Global Positioning System (DGPS)
- Inertial Reference Unit/Attitude Heading Reference Set (IRU/AHRS)
- Air Data Computer
- Radio/RADAR/Laser Altimeter (R/A)
- Traffic Collision Avoidance System (TCAS)

- Data Link (aggregate of IFF Mode S, ADS/B, etc.)

2.0 METHODOLOGY

The process of concept selection decided upon by the industry and government SVS Team members consisted of the following five steps:

1. Conduct a literature review, concentrating on previous studies, documents and experiments concerning technology availability, human performance, issues identification and resolution, and systems development relating to the Commercial and Business (CAB) aircraft mission.

2. Conduct a review of data and issues with Industry and government (NASA and FAA) SVS team members, to determine SVS related requirements and issues, select candidate technologies, and list operational considerations and concerns related to the CAB mission.

3. Conduct analysis, trade studies, and experimentation to refine issues and requirements, and develop a list of candidate technologies to resolve them.

4. From the above results, select and develop a Candidate Concept, which has the best potential for satisfying system requirements, as well as providing the best balance in system performance, weight, support requirements, technical risk, certification cost and risk, and manufacturing cost and risk.

5. Refine the definition and functions endemic to the Candidate Concept, as inputs from subject matter experts and results from experiments are obtained.

Steps one through four are ongoing, and preliminary results delivered in previous documents. This document addresses step four in the concept selection process and provides the current characterization of the baseline SVS system design. Step five is an ongoing task to monitor efforts to further define or validate SVS design requirements and to evaluate technology demonstrations. This step continually evaluates the current baseline SVS concept in light of these requirement and technology refinements.

The majority of the evaluation comments presented herein are based on the engineering judgment and experiences of subject matter experts associated with, or having worked on, the various technologies on this (SVS) project, the High Speed Research (HSR) Program, and other Synthetic Vision programs.

3.0 CONCEPT CHARACTERIZATION

3.1 GENERAL.

The following is a description of the present SVS Candidate Concept and a general overview for the Commercial and Business (CAB) aircraft SVS Mission. It represents a summary of what has been written and discussed to date by the SVS Group relating to the concept and mission, gleaned from analysis, lab tests, ground simulation, and flight test.

3.2 COMMERCIAL AND BUSINESS SVS MISSION DESCRIPTION

3.2.1 General Mission Description

SVS will enable enhanced safe and consistent gate-to-gate aircraft operations in normal and low visibility conditions. The CaB aviation industry believes it is safe and is unlikely to purchase SVS solely for safety's sake, but will purchase SVS for a better capability to accomplish the mission of moving people from Airport A to Airport B. Therefore, the CaB SVS must be focused on operational benefits through mission accomplishment for aviation industry acceptance. SVS will support safe aircraft operations gate-to-gate (taxi, departure, en route, arrival/missed approach, landing, taxi, shutdown). It may be feasible to apply SVS technology in zero visibility. However, Category IIIc or "zero/zero " operations are not an approved operation at this time, and the weather minimums that would require Category IIIc use are rare. Furthermore, conducting "zero/zero" operations requires enhanced equipage of emergency response vehicles. Consequently, the focus of the CAB SVS Mission will be on facilitating operations in normal and "low visibility" or Category IIIb or better visibility conditions. For departure and ground operations, the SVS goal is to enable head-down operations with an RVR of 300 feet. SVS will potentially allow greater operational flexibility, such as permitting aircraft to taxi, depart, and arrive in Category IIIb visibility while using Category I equipped airports and runways. Therefore, the potential operational benefits are also a major area of consideration.

Safe operations in the various mission phases involves two primary areas – acceptable manual or autopilot path control, and hazard avoidance. Acceptable path control implies the ability to manually or automatically configure navigation and control systems to fly a cleared or desired path, and the ability to stay on that path, to required navigational performance, given the aggregate of system and crew capabilities. Acceptable hazard avoidance implies the ability to detect potential hazards, identify and categorize them with respect to threat level and expected future actions, make decisions regarding necessary avoidance maneuvers, and assess the effectiveness of those maneuvers, if required.

3.2.2 Path Control

Successful path control presupposes the ability of the crew or system to identify the cleared or desired path, and configure aircraft systems to display and/or fly that path. Systems configuration will involve strategic and tactical display elements. Strategic elements are those indicating in an aggregate sense where the aircraft is going (ideally in a four dimensional manner), as in a Navigation Display. Tactical elements typically indicate more direct path control requirements, such as required pitch or bank angle changes to maintain desired path, as in a flight director on a Primary Flight Display. The SVS Concept involves enhancements in both of these areas.

3.2.3 Hazard Avoidance

3.2.3.1 Elements

Successful hazard avoidance involves the following elements:

- **Detection**. Sensing that a specific potential hazard exists in a position to be a present or future threat. Detection may be through direct visual contact (optical windows), raw presentation of imaged sensor data (as in Forward Looking Infrared imagery), or display of data interpreted or filtered through processing sub-systems (as in symbolic or iconic representation of objects). SVS Concept components potentially involve enhanced detection of hazards, through dedicated sensors (i.e., FLIR, MMW), or enhanced features in existing sensors (Weather RADAR).
- **Identification**. Categorization of potential external threat by phase of flight (ground or airborne), vehicle type (i.e., aircraft, ground vehicle, terrain, animal life), and vehicle subclass (large, medium or small, or specific type). SVS Concept components potentially involve enhanced identification of hazards, through dedicated Image Object Detection and Fusion computation equipment.
- **Geometry Awareness**. Determination of relative range, relative altitude, object aspect angle (i.e., nose-on, tail-on, right or left side), and expected motion (closure and angular drift). SVS Concept components potentially involve enhanced geometry awareness, through dedicated Image Object Detection and Fusion computation equipment, and enhanced display features (iconic perspective representation of hazardous traffic).
- **Prioritization**. Determination of the significance of the anticipated threat, immediacy and proximity of closest point of approach, based on anticipated motion of object and own aircraft. Generally accomplished by the crew or augmented with TCAS. SVS Concept components potentially involve enhanced prioritization of hazards, through dedicated Image Object Detection and Fusion computation equipment.
- **Action Decision**. The decision as to which action, if any, is appropriate, with regard to aircraft maneuvering or communication, to maintain safe separation with the potential threat object. Generally accomplished by the crew or augmented with TCAS.
- **Action Assessment**. Sensing of sufficient information relating to the relative success of the maneuver decided upon (including the potential decision not to maneuver) in achieving the desired goal of maintenance of safe separation. May

include further iteration of action decision and feedback. Generally accomplished by the crew or augmented with TCAS.

- **Overall Situation Awareness**. Maintenance of a clear mental picture, among all aircraft crew members, relating to the presence and potential future threat of airborne and ground external objects, including the ability to weigh the consequences of future path control decisions based on this mental picture. SVS Concept components potentially involve enhanced overall hazard situation awareness, through dedicated Image Object Detection and Fusion computation equipment, and enhanced display features (iconic perspective representation of hazardous traffic).

3.2.3.2 Specific Hazards

The hazard avoidance mission will include the above functions relating to potentially hazardous objects. SVS Concept elements providing hazard avoidance augmentation will, of necessity, have to consider several categories of hazards (or at least make assumptions concerning coverage). To present a clear path to a runway stop, for instance, on an SVS display when one of the below categories of hazards exist, could be construed as misleading information. Objects of interest will include the following.

- **Cooperative traffic**. Those ground or airborne objects obeying known clearances and equipped with IFF and accurate navigational equipment. ADS/B, ASDE, and TCAS, as examples, may be used to detect and display this category of hazard.
- **Uncooperative traffic**. Those ground or airborne man-made objects not obeying or in receipt of a known clearance and/or not equipped with standard navigation and IFF equipment. Detection of these hazards must be made through own-aircraft sensors, or ground sensors and a communication path (radio or data link) to own aircraft.
- **Terrain**. Natural (presumably charted) ground features of significance to ground or airborne navigation and safety. This category of hazard may be “sensed” through the presence of an onboard data base, however, integrity and reliability of that data base are severe operational constraints which must be addressed. Given the stringent reliability requirements for equipment critical to safe Commercial and Business aircraft operations, it is likely that use of a data base must be augmented with equipment intended to assure accuracy of presented information.
- **Cultural Features**. Man-made structures (i.e., towers, buildings, wires, etc.) of significance to ground or airborne navigation and safety. Given the stringent reliability requirements for equipment critical to safe Commercial and Business aircraft operations, as well as data base maintenance requirements (to display a newly constructed tower, for example), it is likely that use of a data base must be augmented with equipment intended to assure accuracy of presented information.
- **Wildlife**. Ground and airborne animals of significance to ground or airborne safety. Typically, these are sensed and controlled visually, either by the crew, or by airport personnel, or both.

3.3 SYNTHETIC VISION SYSTEM COMPONENTS.

The following is a description of the components, which define the present SVS Concept, for purposes of this document.

3.3.1 General.

Several Workshops, discussion with subject matter experts, literature review, analysis, and laboratory, simulation, and flight test experiments have resulted in an evolving baseline concept which may be reasonably expected to meet the above mission requirements. The baseline concept is intended to frame mission requirements and potential solutions in the context of defined technology, rather than to represent a specific design solution. Specific components used in flight test and simulation experiments are described in the requirements documents relating to those experiments. Figure 3.1, below, presents an overview of concept architecture and functional relationships. The following briefly discusses each of the components, including variations within the team concerning configuration and/or use of the components.

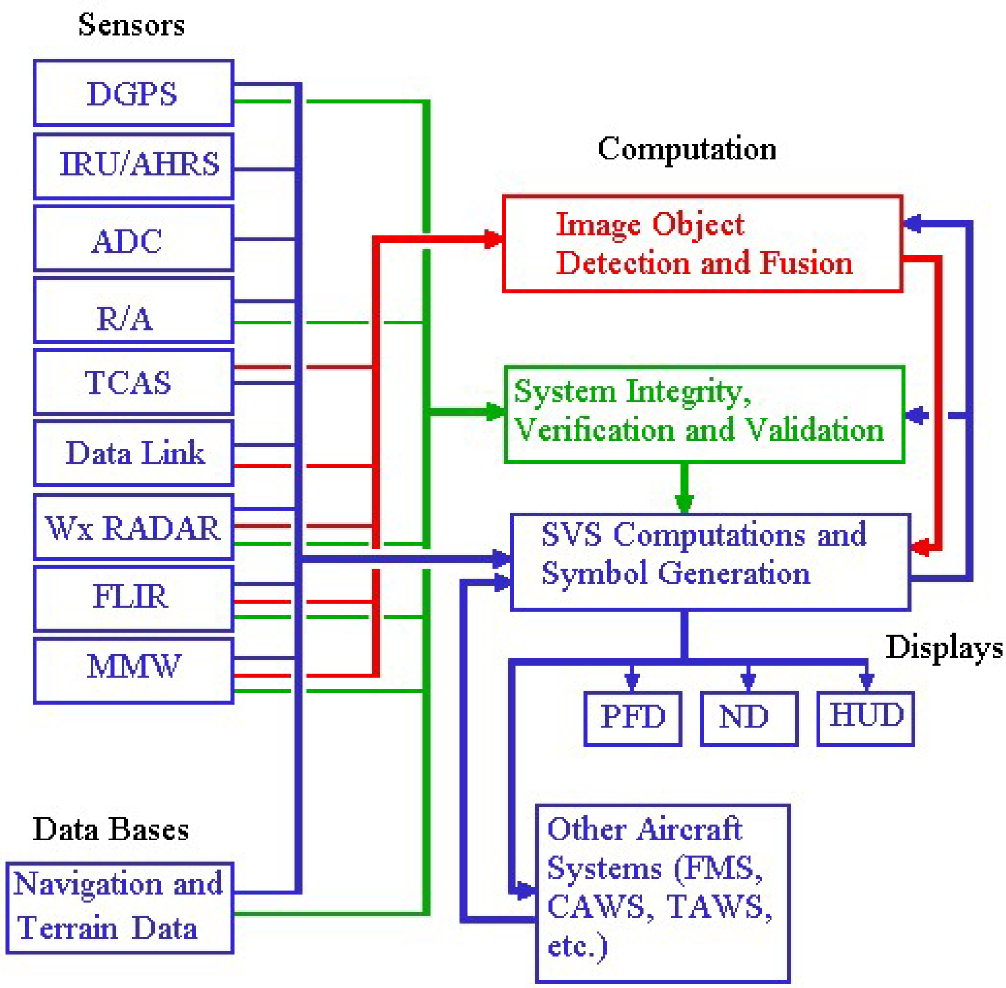

Figure 3.1
SVS Concept Architecture Overview

3.3.2 Sensors

The following is a functional description of the primary sensors listed in Figure 3.1, which characterize the SVS Concept. Sensors are included herein which are dedicated to SVS Mission accomplishment, as well as other aircraft system sensors.

3.3.2.1 Differential Global Position System (DGPS)

DGPS (in concert with IRU) is the primary SVS navigational source. This sensor subsystem is considered part of the standard aircraft suite, but has interface functions unique to SVS. DGPS provides primary position solution data for SVS Computations and Symbol Generation, as well as System Integrity, Verification and Validation function.

3.3.2.2 Inertial Reference Unit/Attitude/Heading Reference Set (IRU/AHRS)

This is the primary source for attitude, heading (true and magnetic), track, and wind information for SVS Mission accomplishment. This sensor subsystem is considered part of the standard aircraft suite, but has interface functions unique to SVS. This subsystem provides data for SVS Computations and Symbol Generation function.

3.3.2.3 Air Data Computer (ADC)

This is the primary source for Calibrated Airspeed, Pressure Altitude, Mach Number, and Vertical Speed (rate of change of Pressure Altitude). This sensor subsystem is considered part of the standard aircraft suite, but has interface functions unique to SVS. This subsystem provides data for SVS Computations and Symbol Generation function.

3.3.2.4 Radio/RADAR/Laser Altimeter (R/A)

This subsystem is the primary source for Altitude above ground information. R/A is considered part of the standard aircraft suite, but has interface functions unique to SVS. This subsystem provides data for SVS Computations and Symbol Generation function.

3.3.2.5 Traffic Collision Avoidance System (TCAS)

This subsystem provides position data with respect to other aircraft equipped with TCAS, and generates advisories and warnings with respect to aircraft significant to collision avoidance. This sensor subsystem is considered part of the standard aircraft suite, but has interface functions unique to SVS. This subsystem provides data for SVS Computations and Symbol Generation, as well as Image Object Detection and Fusion functions.

3.3.2.6 Data Link

For purposes of the present SVS Concept characterization, Data Link is a collection of subsystems which receive information from external sources (ground and/or airborne) concerning external traffic. For example, Automatic Dependent Surveillance/Broadcast (ADS/B) data would be included here. This sensor subsystem is considered part of the standard aircraft suite, but has interface functions unique to SVS. This subsystem provides data for SVS Computations and Symbol Generation, as well as Image Object Detection and Fusion functions.

3.3.2.7 Weather RADAR (WxR)

This sensor subsystem provides data with respect to other air (and potentially, surface) traffic. The ability of this system to detect ground and airborne hazards (other than weather related ones) is a function unique to SVS, and may potentially involve WxR hardware and/or software changes, in addition to those required for SVS interfaces. This subsystem provides data for Image Object Detection and Fusion; System Integrity, Verification and Validation; and SVS Computations and Symbol Generation functions.

3.3.2.8 Forward Looking Infrared (FLIR)

This sensor subsystem provides an infrared spectrum view of a field of regard in the aircraft's forward quarter, and potentially image information useful for system integrity monitoring, object detection, and path control. This system is one unique (as presently envisioned) to SVS. Raw data would be in the form of a video image. This subsystem provides data for Image Object Detection and Fusion; System Integrity, Verification and Validation; and SVS Computations and Symbol Generation functions. Requirements for FLIR, if any, are being assessed by the Project Team.

3.3.2.9 Millimeter Wave RADAR (MMW)

This sensor subsystem provides a millimeter wave spectrum image of a field of regard in the aircraft's forward quarter, and potentially image related information useful for system integrity monitoring, object detection, and path control. This system is one unique (as presently envisioned) to SVS. Raw data would be in the form of scanned RADAR returns, azimuth versus range, at incrementally selected elevations. This subsystem provides data for Image Object Detection and Fusion; System Integrity, Verification and Validation; and SVS Computations and Symbol Generation functions. Requirements for MMW, if any, are being assessed by the Project Team.

3.3.3 Data Bases

Data bases listed in Figure 3.1, which characterize the SVS Concept, include those dedicated to SVS Mission accomplishment, as well as other aircraft system data bases (Flight Management System navigational data bases, for example). This subsystem provides latitude, longitude, and elevation data for terrain and man-made structures of potential significance to hazard avoidance. The SVS dedicated data base may involve nested components in hardware and/or software, with varying resolution and accuracy, appropriate to the phase of flight anticipated in the represented region. This subsystem provides data for System Integrity, Verification and Validation, and SVS Computations and Symbol Generation functions.

3.3.4 Computational Subsystem Components

The following subsystems satisfy requirements for integration and accomplishment of computational functions associated with SVS Mission accomplishment. Computational subsystems may be in the form of dedicated computers, or imbedded hardware and/or software in other computers, either dedicated to SVS, or part of the other aircraft subsystems.

3.3.4.1 Image Object Detection and Fusion Computation Function

This computational subsystem receives data from TCAS, Data Link, Weather RADAR, FLIR, and Millimeter Wave RADAR subsystems, with regard to potential airborne or ground hazards. It receives data from the SVS Computations and Symbol Generation subsystem with regard to aircraft state and navigation (for use in reasonability tests, for example). This subsystem performs the following functions using these data:

- Data confidence, detection threshold filtering, expected error, source data reasonability and integrity estimation
- Hazard detection
- Data fusion (correlated position of potential hazards)
- Image enhancement and fusion, where appropriate
- Integrity self monitoring and alerting

3.3.4.2 System Integrity, Verification, and Validation Computation Function

This computational subsystem potentially receives data from DGPS, R/A, Weather RADAR, FLIR, Millimeter Wave RADAR subsystems, and Navigation and Terrain Data Bases, with regard to own aircraft position, expected terrain or obstacle height, and actual terrain or obstacle height. It receives data from the SVS Computations and Symbol Generation subsystem with regard to aircraft state and navigation (for use in reasonability tests, for example). This subsystem performs the following functions using these data:

- Data Base reliability, integrity, expected error
- Other source data reasonability and integrity estimation
- Generate appropriate system alert messages
- Integrity self monitoring and alerting

3.3.4.3 SVS Computations and Symbol Generation

This computational subsystem receives data from all the sensors and data bases described above in Sections 3.3.2 and 3.3.3, with respect to aircraft position and state, as well as sensed external position and hazards. It receives data from the System Integrity, Verification and Validation computational subsystem with regard to data base and other systems integrity, and the Image Object Detection and Fusion Subsystem with regard to hazard detection, identification, prioritization, hazard situation, and fused sensor imagery. It receives data from other aircraft systems with respect to cleared path, terrain hazards (TAWS), and system integrity and status. This subsystem performs the following upper level functions using these data:

- Cleared and actual path depiction
- Hazard element display integration and depiction
- Runway Incursion Prevention System algorithm computation and display
- Hold Short and Landing Technology algorithm computation and display
- Navigation and hazard situation awareness enhanced display element generation
- Alert and warning generation and presentation
- Overall display symbol generation and/or SVS integration
- Integrity self monitoring and alerting

3.3.5 Displays

The following is a functional description of the primary displays listed in Figure 3.1, which characterize the SVS Concept. Display configurations may be dedicated to SVS Mission accomplishment, for example, in a dedicated Primary Flight Display. Alternately, they may be integrated into conventional aircraft display subsystems, as in a dedicated page on a multifunction Navigation Display, or imbedded SVS features in a conventional Navigation Display page. Display formats are extremely implementation specific, and variations exist among SVS Team members. Three primary configurations exist – one developed by NASA, one developed by Rockwell Collins, and one developed by British Aerospace. For each of the display components, representative formats will be shown for each of the groups. It should be kept in mind, however, that display formats are the most volatile of the SVS Concept characterization elements, as they change rapidly for each of the flight test and simulation experiments, and as the Team learns and interacts. Formats, then, are predominantly examples of what might be done in SVS implementation, rather than strict elements of the Concept definition.

Displays are assumed to receive SVS specific information from the SVS Computations and Symbol Generation computational subsystem. Information paths for other functions in these shared displays may exist separate from SVS components, for example, in FMS status or inputs directly to the Navigation Display.

3.3.5.1 Primary Flight Display (PFD)

The PFD provides primary tactical (and to some extent, strategic) guidance for path control and hazard avoidance. In the present concept, this is a head down (below the glareshield) instrument. Issues of scale, size of the display, the presence and nature of terrain perspective cues, and guidance format are significant research issues which are being addressed by the Team. Specific examples of PFD formats used by SVS Team members are presented below. Detailed descriptions of all the formats used for a particular experiment may be found in the requirements documents relating to those experiments.

Figure 3.2 presents an example NASA SVS Research Display PFD format. In experiments to date, the NASA PFD format has been collocated with the ND, on the same research display. In the NASA PFD, terrain modeling has been either generic texture overlaid on elevation data, or photo-realistic textured data. Research will help where each might have advantages over the other.

Figure 3.3 presents an example Rockwell Collins Research Display PFD format. As in the case with NASA formats, the Rockwell Collins format collocated the PFD and Navigation Displays on the same display. In the case of terrain depiction, the Rockwell Collins format used only generic terrain, to facilitate economical and quick implementation.

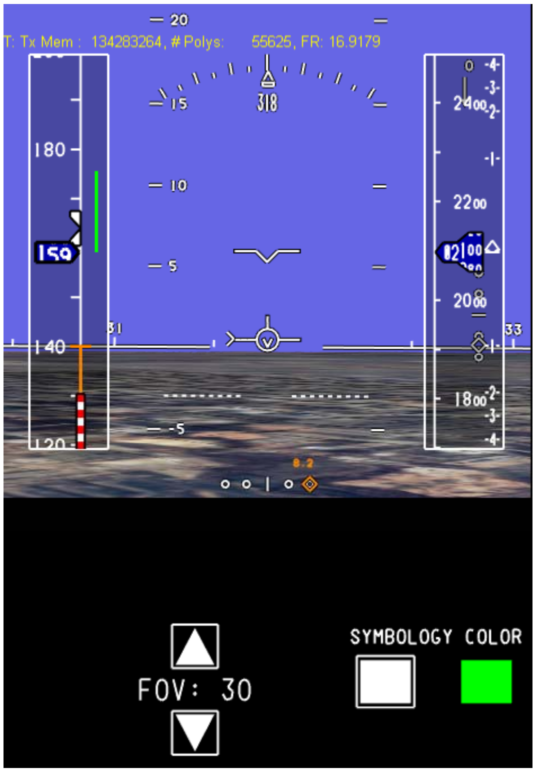

Figure 3.2
Example NASA PFD Format

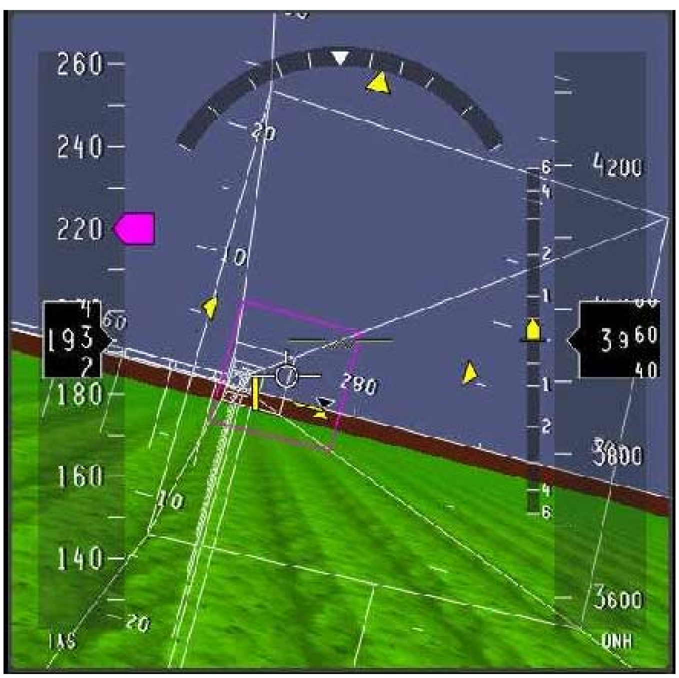

Figure 3.3
Example Rockwell Collins PFD Format

Figure 3.4 presents an example British Aerospace (BAe) Research Display PFD format. As in the case with NASA formats, the BAe format is expected to collocate the PFD and Navigation Displays on the same display (testing will commence in Spring 2001).

Graphic Requested, to
be Provided

Figure 3.4
Example British Aerospace PFD Format

3.3.5.2 Navigation Display (ND)

The ND provides primary strategic information for path control support, and hazard avoidance. In the present concept, this is a head down (below the glareshield) instrument. Issues of scale, size of the display, the presence and nature of traffic hazard cues, and overall format are significant research issues which are being addressed by the Team. Specific examples of ND formats used by SVS Team members are presented below. Detailed descriptions of all the formats used for a particular experiment may be found in the requirements documents relating to those experiments.

Although development of a NASA strategic display is scheduled for FY 2001, NASA has used a conventional format Navigational Display in conducting research in other areas. Figure 3.5

presents this example NASA SVS Research Display ND format. In experiments to date, the NASA ND format has been collocated with the PFD, on the same research display.

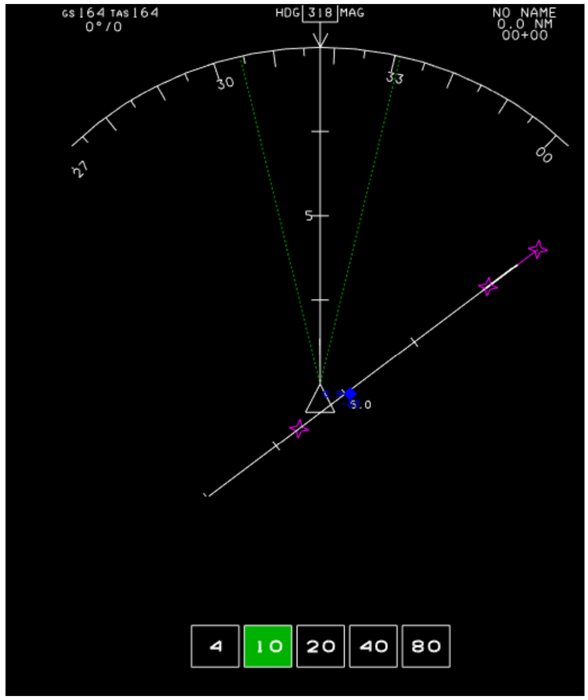

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Figure 3.5
Example NASA ND Format

The NASA SVS Team also tested another ND format, specific to Runway Incursion Prevention System and Hold Short and Landing Technology flight and simulation testing. This format is presented in Figure 3.6. In subsequent tests, basic SVS, RIPS and HSALT formats are expected to be integrated.

Figure 3.6
Example NASA RIPS ND Format

Figure 3.7 presents an example Rockwell Collins Research Display ND format. As in the case with NASA formats, the Rockwell Collins format collocated the ND and Primary Flight Displays on the same display.

Figure 3.7

Example Rockwell Collins ND Format

Figure 3.8 presents an example British Aerospace Research Display ND format. As in the case with NASA formats, the BAe format is expected to collocate the ND and Primary Flight Displays on the same display (testing will commence in Spring 2001).

Graphic Requested, to
be Provided

Figure 3.8
Example British Aerospace ND Format

3.3.5.3 Head Up Display (HUD)

The HUD provides primary tactical (and to some extent, strategic) guidance for path control and hazard avoidance. In the present concept, depiction of real world cues (symbolic and perspective) is conformal, with respect to location and scale of the cue. Issues of the nature of terrain perspective cues, and specific guidance format, are significant research issues which are being addressed by the Team. Specific examples of HUD formats used by SVS Team members are presented below. Detailed descriptions of all the formats used for a particular experiment may be found in the requirements documents relating to those experiments.

Figure 3.9 presents an example NASA SVS Research Display HUD format. In the NASA HUD, terrain modeling has been either generic texture overlaid on elevation data, or photo-realistic textured data. Research will help where each might have advantages over the other.

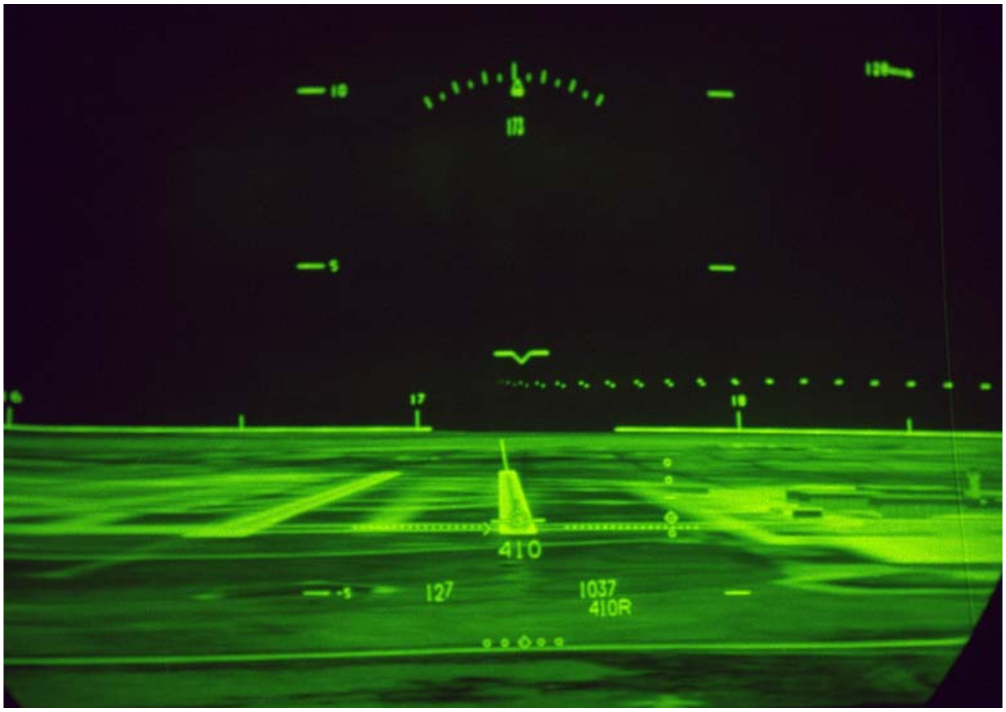

Figure 3.9
Example NASA HUD Format

The NASA SVS Team also tested two additional HUD formats, specific to Runway Incursion Prevention System and Hold Short and Landing Technology flight and simulation testing. The RIPS HUD Format is presented in Figure 3.10, and the HSALT Format in Figure 3.11. In subsequent tests, basic SVS, RIPS and HSALT formats are expected to be integrated.

Figure 3.10
Example NASA RIPS HUD Format

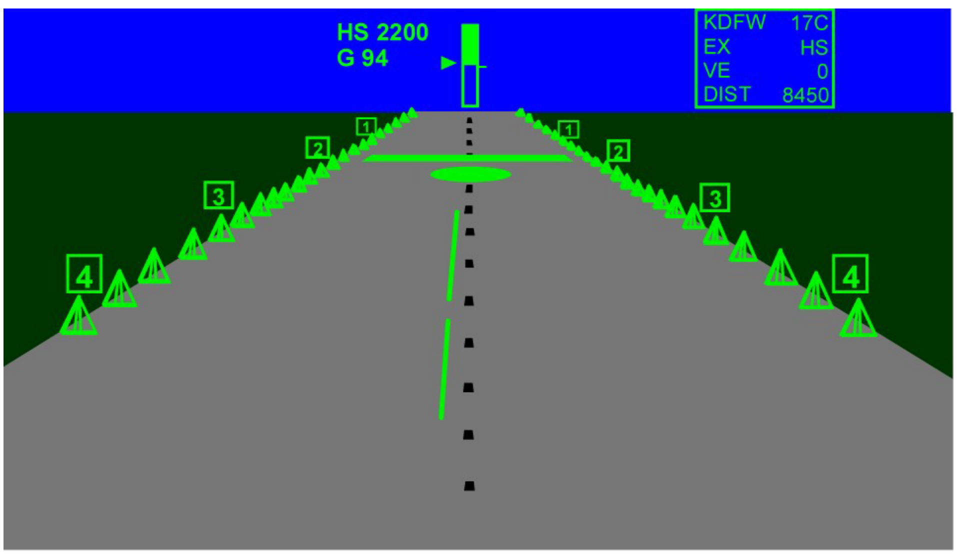

Figure 3.11
Example NASA HSALT HUD Format

4.0 CONCEPT ASSESSMENT DISCUSSION

The following are assessments of significance to the characterization of each of the SVS Concept element areas, gleaned from results of experiments, and analytical studies to date. A detailed discussion of SVS Concept assessment is presented in the Fiscal Year 2000 Concept Assessment Document, along with a detailed list of experiments this Fiscal Year, and a catalog of critical SVS issues identified by the Team.

4.1 GENERAL

The experiment and demonstration at Asheville near the beginning of the Fiscal Year afforded an excellent early look at the potential for SVS in augmenting path control and situation awareness in mountainous terrain. This experiment showed promise in the ability of displays using synthetic imagery gleaned from onboard data bases, to augment pilot path control and situation awareness functions. This experiment also suggested some tolerance in pilot use of terrain texture cues, leading to subsequent experiments on the nature of those cues, and the terrain modeling options listed in the current Concept.

Initial simulation experiments and concept development helped narrow the scope of test for subsequent flight test, by identifying the likely range of operational acceptability in the extent of Primary Flight Display size and fields of view. The simulator was also very useful in developing flight test scenarios, timing, and procedures. Much of what was learned in the simulator with regard to pilot preference and overall flight operations was verified in the following flight test.

The team conducted an excellent workshop concerning the concept of SVS operations, which brought a significant user community presence into the project. Inputs from manufacturers, airline operators and managers, and regulatory agencies have added considerably to the Concept, by identifying issues and potential benefits in future SVS-equipped operations.

The flight test at Dallas offered an extensive operational look at an early SVS configuration, in a flat terrain, culturally dense environment. A significant amount of quantitative and qualitative data were taken at Dallas, much of which is still being analyzed. Although problems were identified, in general there was widespread acceptance among airline Captains acting as Evaluation Pilots, of the overall SVS philosophy and concept. The presence of database imagery on the HUD and PFD was relatively well received, and pilots felt the information content and display methodology useable. Results from the experiment comparing photo-realistic versus generic terrain depiction indicate that, depending on size of display and nature of image information, each has advantages.

A specific discussion of SVS Concept elements and assessment follows, by component.

4.2 FORWARD LOOKING INFRARED (FLIR)

Efforts this Fiscal Year have been devoted predominantly to design and installation issues associated with the planned installation of a FLIR sensor package in the NASA 757 test vehicle this Winter, to support Spring flight tests at Eagle/Vail.

FLIR implementation can potentially support path control through direct presentation of scene imagery to the pilot, object detection (either directly through pilot scene interpretation, or automatically), and data base integrity assurance.

4.3 WEATHER RADAR (POTENTIAL SVS MODES)

Efforts this Fiscal Year have been devoted predominantly to data collection and analysis. Weather RADAR data based algorithms may potentially provide benefits in two key areas: database integrity monitoring, and ground object hazard avoidance. A key advantage of this scheme is that it uses equipment already present on commercial aircraft (though equipment availability of this non-critical system is an issue). The operational feasibility of use of existing RADAR data sources, combined with new algorithms, for these purposes, is largely untried in the commercial and business environment. Significant development and test is required to develop and prove utility of this concept prior to industry acceptance.

4.4 MILLIMETER WAVE RADAR

No significant testing efforts involving Millimeter Wave (MMW) RADAR have occurred this Fiscal Year, other than limited discussions on potential future flight test opportunities.

MMW implementation can potentially support path control through direct presentation of scene imagery to the pilot in low visibility conditions, object detection (either directly through pilot scene interpretation, or automatically), and data base integrity assurance.

The methodology for operational employment of MMW in a commercial and business aircraft environment is largely untried or unproven, as well, and operational risk is therefore considered high.

4.5 GLOBAL POSITIONING SYSTEM

Global Positioning System (GPS), even with differential corrections required for precision path control accuracy, is considered a relatively mature technology, with numerous off the shelf systems available, or being tested in their final forms. Though there are integrity, reliability, and criticality issues which remain before GPS is ready to support a fully implemented SVS-equipped airline fleet, the technology is relatively mature.

4.6 ONBOARD SVS DATA BASE

Significant efforts have occurred this Fiscal Year in learning how to obtain source data for an SVS data base, and assemble it in simulation and flight test hardware and software. Issues associated with streamlining this process, and with the ability to guarantee accuracy, maintainability, availability, and integrity of the data base are currently being addressed. The decision to incorporate such a data base in the SVS Concept is supported by assumptions that the resulting infrastructure requirements won't result in prohibitive product costs, and that world-wide terrain elevation data will eventually become readily available.

4.7 SYSTEM INTEGRITY MONITORING

Given that certain conceivable failures of the data base could cause loss of an aircraft, the team believes this system to be critical to flight safety, and therefore is required to meet commercial critical reliability standards. It is further believed that, given the data collection methodology and the potential for data to change over time (man-made or natural terrain changes, tower construction, etc.), a necessity exists for an separate SVS component to assure data base integrity. The exact nature for this component, and required technology, is at present unknown (though potential candidates have been identified). Efforts this year have identified two sensor sources to support this function – Weather RADAR and RADAR or LASER altimeter. No significant testing, however, has been accomplished to date.

4.8 OTHER ONBOARD NAVIGATION SYSTEMS AND DATA BASES

Though not representing new SVS equipment being added to an existing aircraft concept, SVS will certainly require information from other onboard aircraft systems, like attitude and heading from an Inertial Measurement Unit, altitude and airspeed from an Air Data Computer, cleared and desired path from a Flight Management System, etc. The nature of the interface between SVS and these systems, and the extent to which these associated functions are imbedded within SVS components, will depend on whether the SVS is a retrofit, or a new implementation. In any case, implementation details are envisioned to be workable for retrofit or new aircraft installations.

4.9 PRIMARY FLIGHT DISPLAY, OR IMBEDDED DISPLAY FEATURES

Since the size of the Primary Flight Display, and available display surface for SVS display components will vary depending on whether the installation is in a new aircraft, or a retrofit solution, the SVS Project has investigated size and field of view issues on Primary Flight Displays, both in simulation, and in flight test. Results indicate that mission tasks can be performed across the gamut of anticipated display sizes. Certification efforts associated with major changes in a Primary Flight Display are traditionally extensive, however.

4.10 NAVIGATION DISPLAY, OR DISPLAY FEATURES/PAGES

Flight and simulation testing this year have used Navigation Display formats which are relatively mature, and generally well accepted by the evaluation pilots. The elements of this component are likely to be well integrated with existing hardware in the commercial and business aircraft mission environment. SVS elements of the Navigation Display will likely be combined on existing pages in a multi-function display, or be placed on dedicated pages. It is likely that SVS components can be implemented which will augment mission performance without adverse impact, both on new and retrofit installations. Certification efforts associated with major changes in this display are traditionally extensive, however.

4.11 HEAD UP DISPLAY (OPTION) WITH DEDICATED DISPLAY FEATURES

Flight and simulation testing this year have used a Head-Up Display tailored and configured for SVS testing, with both raster image and symbolic elements. The philosophy to date has been to employ the HUD as an augmentation to path control and situation awareness, rather than as a Primary Flight Display. In retrofit applications, involving analog displays, HUD would be employed as a Primary SVS tactical Display, but the philosophy would still be to consider the existing head down PFD as the Primary Flight Display. The use of an image on a HUD in this role, however, is largely untried previous to the present experiments (albeit well accepted by pilots to date). Results to date, however, support its continued presence in the SVS Concept.

4.12 INTERFACE WITH OTHER COCKPIT DISPLAYS, I.E., TAWS

Generally, efforts in this area have been limited to studies, or work that is in planning. No significant results exist to date, but are planned for early Fiscal Year 2001. Implementation details are envisioned to be workable for retrofit or new aircraft installations.

4.13 DEDICATED SVS SUPPORT EQUIPMENT AND CREW INTERFACE

This SVS component consists of equipment and controls necessary for crew interface to the SVS, i.e., mode controls, brightness and contrast controls, Flight Guidance interfaces (particularly mode transition and awareness), and flight path control workload alleviation features (autoflight modes). No specific studies were conducted this year in this area, though crew interface provisions were incorporated in all tests. Implementation details for support equipment and crew interfaces are envisioned to be workable for retrofit or new aircraft installations.

4.14 INTERFACE WITH OTHER AIRCRAFT SYSTEMS

No specific studies were conducted this year in this area, though aircraft system interfaces were required and incorporated in all tests. Implementation details for interfaces with other aircraft systems are envisioned to be workable for retrofit or new aircraft installations.

5.0 SUMMARY

This Fiscal Year has seen substantial progress in the maturing of an SVS Concept with the potential for meeting the goals of the Gore Commission in the area of Controlled Flight Into Terrain, as well as providing significant operational and marketing benefits to commercial and business aircraft owners and operators.

The architecture of an implementable SVS, capable of meeting significant mission requirements, has been identified. Key components of the Concept have been tested in real-world operational environments, and show promise in meeting identified requirements.

An update to this document will be prepared at the end of Fiscal Year 2001, which will present an update to the SVS Concept, following receipt of results from experiments and studies, issues resolution consensus, and metrics assignment.

6.0 ACRONYMS

ADS/B	Automatic Dependent Surveillance/Broadcast
ASIST	Aviation Safety Investment Strategy Team
ATC	Air Traffic Control
AvSP	Aviation Safety Program
AWIN	Aviation Weather Information
CAB	Commercial and Business
CCD	Charge Coupled Device
CDTI	Cockpit Display of Traffic Information
CFIT	Controlled Flight Into Terrain
CHR	Cooper Harper Rating
CONOPS	Concept of Operations
DFW	Dallas/Fort Worth Airport
DGPS	Differential Global Positioning System
DoD	Department of Defense
EGE	Eagle/Vail Airport
EFIS	Electronic Flight Information System
EVS	Enhanced Vision Systems
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FBO	Fixed Base Operator
FLIR	Forward Looking Infrared
FOV	Field of View
FY	Fiscal Year
GB	Gigabytes
GBS	Ground Based System
GPS	Global Positioning System
HDD	Head Down Display
HDTV	High Definition Television
HFOV	Horizontal Field of View
HSALT	Hold Short and Landing Technology
HUD	Head Up Display
IDS	Integrated Display System
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
IRL	Implementation Readiness Level
LAAS	Local Area Augmentation System
LAHSO	Land and Hold Short Operations
LaRC	Langley Research Center
LCD	Liquid Crystal Display
LMI	Logistics Management Institute
LVLASO	Low Visibility Landing and Surface Operations

MB	Megabytes
MCHR	Modified Cooper Harper Rating
MHZ	Megahertz
MMW	Millimeter Wave RADAR
NASA	National Aeronautics and Space Administration
ND	Navigation Display
NIMA	National Imagery and Mapping Agency
PFD	Primary Flight Display
R&D	Research and Development
RADAR	Radio Direction and Ranging
RAM	Random Access Memory
RIAAS	Runway Incursion Advisory and Alerting System
RIPS	Runway Incursion Prevention System
RIRP	Runway Incursion Prevention System
RNP	Required Navigational Performance
RTCA	Radio Technical Commission for Aeronautics
RVR	Runway Visual Range
SA	Situation Awareness
SAE	Society of Automotive Engineers
SF	Stopping Factor
SID	Standard Instrument Departure
SV	Synthetic Vision
SVDC	Synthetic Vision Display Concepts
SVS	Synthetic Vision System
SVSRD	Synthetic Vision System Research Display
SXGA	Pixel Resolution of 1024 by 768
TAP	Terminal Airport Productivity
TAWS	Terrain Awareness System
TCAS	Traffic Collision Avoidance System
TIFS	Total Inflight Simulator
TRL	Technology Readiness Level
VMC	Visual Meteorological Conditions
WAAS	Wide Area Augmentation System

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